AN AERIAL SURVEY FOR MUSKOXEN IN THE NORTHERN SAHTU SETTLEMENT AREA, MARCH 1997

Northwest Territories Resources, Wildlife & Economic Development

103-06950/

AN AERIAL SURVEY FOR MUSKOXEN IN THE NORTHERN SAHTU SETTLEMENT AREA, MARCH 1997

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NORMAN WELLS, NWT

1997

Manuscript Report No. 103

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ABSTRACT

We estimate that there are 1460 ± 920 (95% confidence interval) muskoxen (*Ovibos moschatus*) in the Sahtu Settlement Area north of Great Bear Lake, Northwest Territories. That estimate is based on a stratified systematic strip transect survey flown in March 1997 to determine muskox abundance and distribution. We flew a reconnaissance survey at 10% and followed up with surveying the two areas with most muskoxen at 25% coverage. The estimates are relatively imprecise as the coefficients of variation were 31% and 39% for the 10% and 25% coverage, respectively. Previous surveys in the late 1950s to 1987 revealed muskoxen had spread west and increased in number. Differences in survey methods prevent us from determining the trend in population size but our March survey did reveal that the range expansion west and southwest has continued and that areas of high density have changed since 1987. The current annual quota is 11 muskoxen for the Sahtu and the survey results support increasing the quota to 27 which is 5% of the lower 95% confidence limit (540).

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INTRODUCTION

Muskox (*Ovibos moschatus*) populations within the Sahtu Settlement Area (SSA), as with the Northwest Territories (NWT) as a whole, have undergone a dramatic decline and resurgence from about 1850 to 1997 (Kelsall et al. 1971; Barr 1989, 1991; McLean 1992; Fournier and Gunn 1997). During the second half of the nineteenth century Sahtu Dene and Metis hunters from the communities of Fort Good Hope and Tulita (Fort Norman) sold 2073 muskox skins to Hudson's Bay Company (HBC) posts between 1861 and 1898 (Barr 1989, 1991). Muskox populations across the NWT had dropped so precipitously by 1917 that the Government of Canada banned muskox harvest. Muskoxen had disappeared from many areas including north of Great Bear Lake (Tener 1965; Kelsall et al. 1971; Barr 1989, 1991); Anderson (1930) suggested that there were only "perhaps two or three left" in the area north of Great Bear Lake and west of Coronation Gulf in 1929.

Infrequent aerial surveys for muskoxen flown north of Great Bear Lake and west of the Coppermine River from the 1950's to 1987 indicated a general increase in muskox numbers and range (Tener 1965; Kelsall et al. 1971; Case and Poole 1985; McLean 1992). Case and Poole (1985) surveyed the area from Horton Lake north to Estabrook Lake in March 1983 and estimated 1083 $\pm$ 553 (95% C.I.) muskoxen within a 6712 km^2 area (i.e., density of 160 per 1000 km^2). McLean (1992) surveyed some of the same areas for muskoxen north of Great Bear Lake in August but found only 17 adult (>1-yr-old) muskoxen on transect over the 1620 km^2 area of his flight lines within the SSA, giving a density of 11 muskoxen per 1000 km^2. However, because of differences in survey areas, timing (March versus August) and the two estimate's imprecision, McLean (1992) felt his

data were inadequate to detect changes in distribution or numbers from the previous survey.

As a result of requests from the communities of Colville Lake, Fort Good Hope, and Deline, the Department of Resources, Wildlife, and Economic Development (DRWED) assigned an annual quota of eleven muskoxen (either sex) beginning in the 1994/95 hunting year (01 Jul- 30 Jun). This quota was applied to newly created Wildlife Management Muskox Area C/1-2 (later changed to Unit S Muskox Area MX/01 for 1996/97) with the tags allocated as follows: four each to Deline and Colville Lake, two to Fort Good Hope, and one for Resident Hunting Licence holders on an annual draw basis. While there has been little use of the available tags to date (Table 1), there have been recent enquiries to DRWED about access to tags for outfitted sport hunting around the shores of Great Bear Lake (K. Hickling, pers. comm.).

Given those requests, the 10 years since the last survey, and continued reports of muskoxen expanding south and west of the areas surveyed in 1983 and 1987, I submitted a proposal in October 1996 to the Sahtu Renewable Resources Board (SRRB) for joint funding of a survey with DRWED to update muskox status within the SSA. In addition, we coordinated our survey methods with a similar and simultaneous effort within the Inuvialuit Settlement Region (ISR) to the north (Larter 1997) to complete coverage from Great Bear Lake to the coast of the Arctic Ocean.

Table 1. Annual muskox harvests within the Sahtu Settlement Area, 1994/95 to 1996/97

Year[1]	Deline		Colville Lake		Fort Good Hope		Resident		Total	
	Tags	Harvest	Tags	Harvest	Tags	Harvest	Tags	Harvest	Tags	Harvest
1994/95	4	0	4	0	2	0	1	0	11	0
1995/96	4	1	4	0	2	0	1	0	11	1
1996/97	4	0	4	0	2	0	1	1	11	1
Total	12	1	12	0	6	0	3	1	33	2

[1] Hunting year period is 01 July to 31 June

STUDY AREA

The study area covers 55, 818 km^2 within the Sahtu (Figures 1 and 2) and several major rivers cross the study area: the Anderson, Horton, Hornaday, and Dease. The largest lakes within and bordering the study area are: Great Bear Lake, Colville Lake, Lac des Bois, Horton Lake, Kilekale Lake, Lac Maunoir, and Tunago Lake. While the area west of the Anderson River and along the north shore of Great Bear Lake is generally flat (average elevation 250-400 m), the remainder of the study area features rolling hills with numerous lakes and small ponds. Networks of eskers are prominent in the vicinity of Stopover Lake and the upper Omstead Creek area betweenHorton Lake and McGill Bay on the north shore of Great Bear Lake.

Jacobsen (1979) classified the area into broad wildlife zones (ecoregions). Low lying areas west of the Anderson River, the southwest portion of the study area (Smith Arm region), and much of the north shore of Great Bear Lake are primarily Open Forest (spruce-lichen) with several extensive burns that range from 4 to >25-years-old (Forest Management data files, DRWED). Between the Anderson and Horton Rivers, and south of Horton Lake, is an area of Forest-Tundra Transition; east of Horton River and Lake to the east side of the study area is tundra, both Lush Vegetation Tundra and Sparsely Vegetated Tundra.

The western section of the study area, as represented by Colville Lake, is below treeline and has the long, cold winters and short, hot summers characteristic of the subarctic. The eastern portion of the study area, as represented by Kugluktuk, has a more Arctic climate with low precipitation and summers that are much cooler (Table 2).

Other ungulates in the study area are moose (*Alces alces*) and woodland caribou (*Rangifer tarandus caribou*) below treeline. Barren-ground caribou (*R. t. groenlandicus*) from the Bluenose herd, which was last estimated to number ca. 127,000 in July 1992 (Fraser and Nagy 1992) also occur throughout the study area, although below treeline they are usually present only during winter months. The potential predators of muskoxen in the study area are wolves (*Canis lupus*) and grizzly bears (*Ursus arctos*); black bears (*U. americanus*) and lynx (*Lynx canadensis*) occur below treeline and are potential predators of muskoxen, particularly calves. Population levels of both bear species, wolves, and lynx within the study area are unknown

Table 2. Average annual climatic conditions at Colville Lake and Kugluktuk, NWT. Data from Lopatka et al. (1990).

Community	Location	Annual Precipitation Means (cm)			Jan. Mean Temp (°C)		Jul. Mean Temp (°C)	
		Snow	Rain	Total	High	Low	High	Low
Kugluktuk	67° 02' N, 126° 07' W	100.7	10.3	20.2	-26.4	-33.8	13.8	5.6
Colville Lake	67° 02' N, 126° 07' W	115.1	14.7	26.2	-25.6	-34.4	22.9	7.6

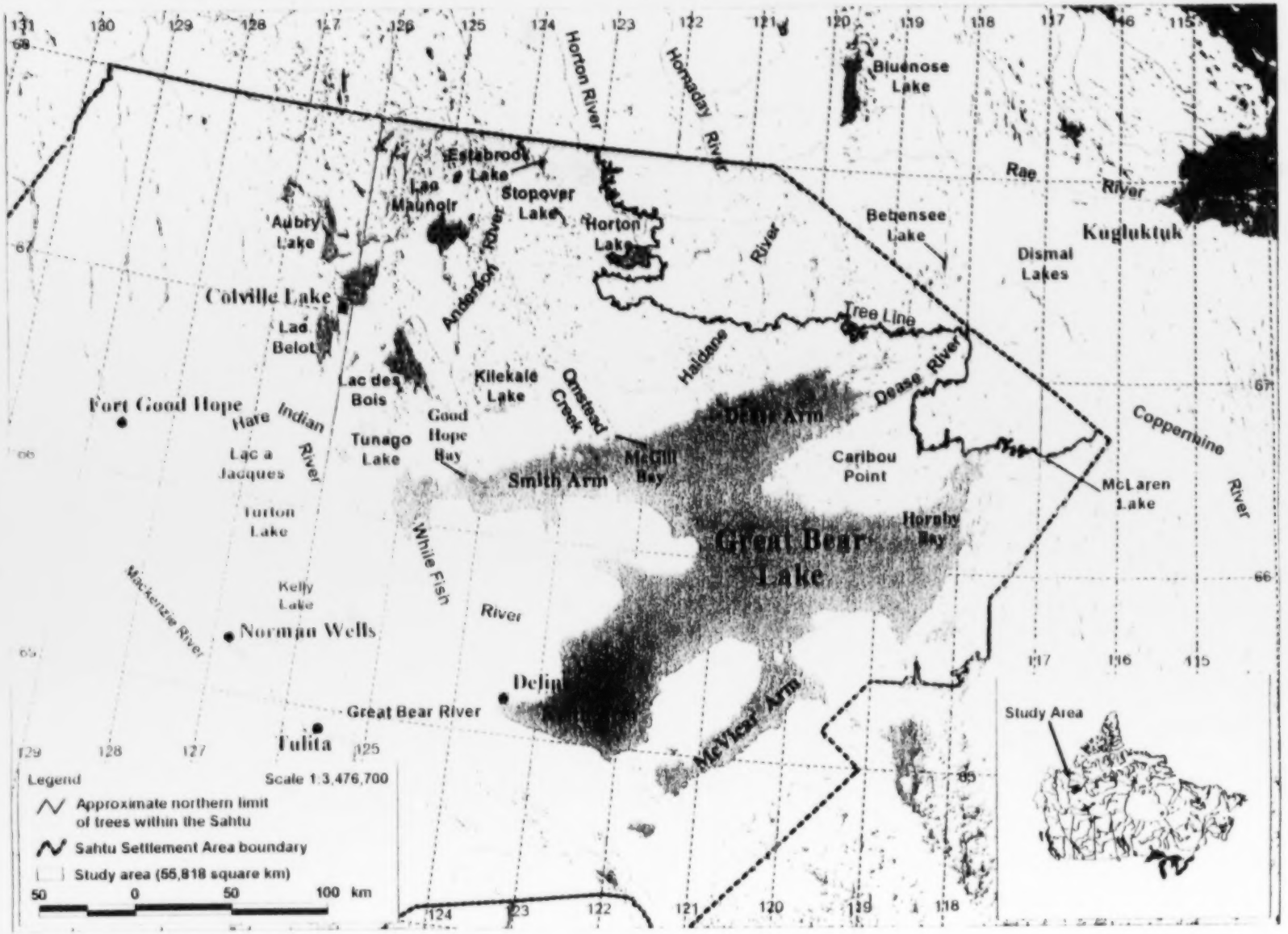

Figure 1. Study area for an aerial survey of muskox in the Sahtu Settlement Area, March 1997

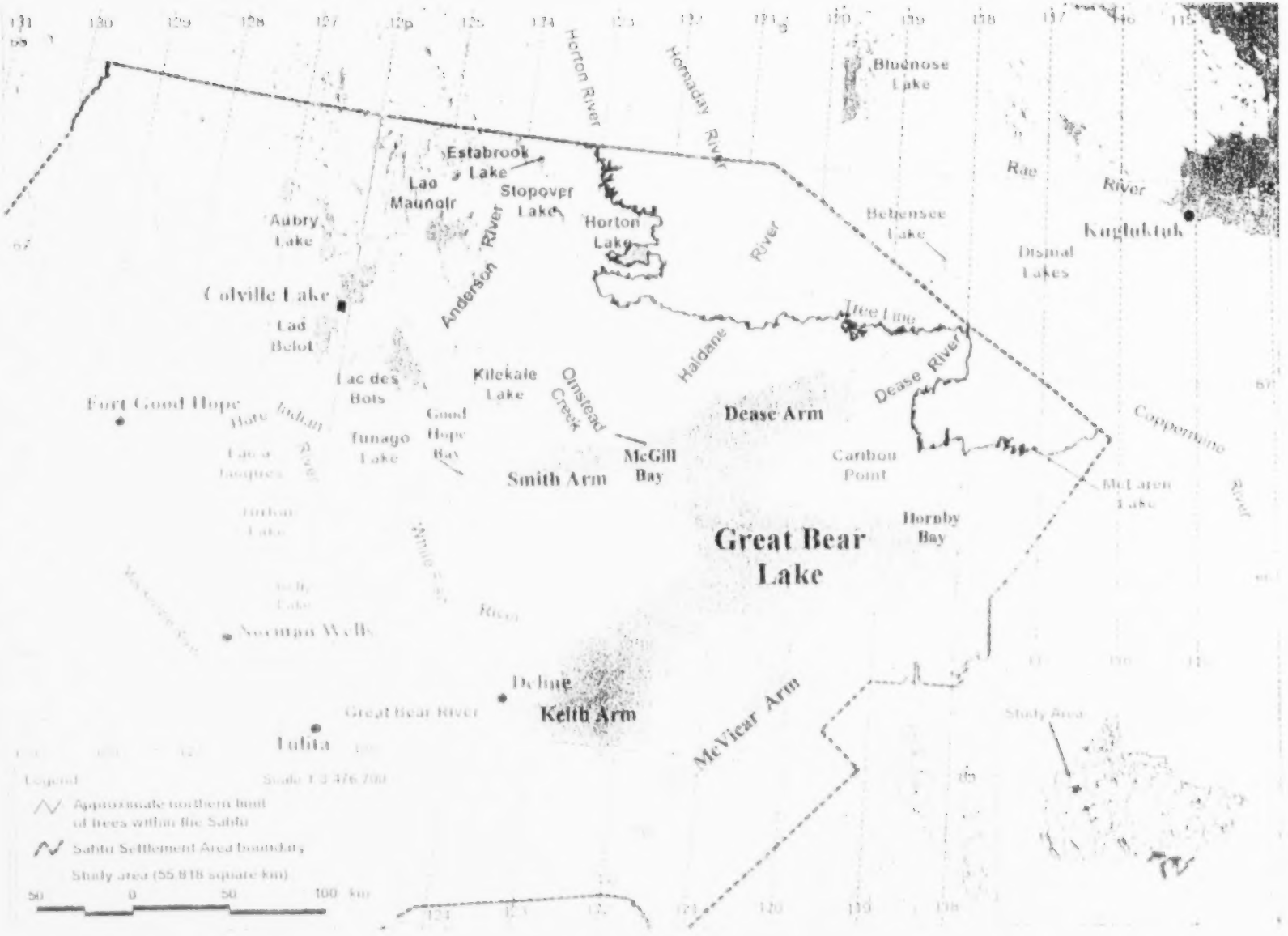

Figure 1. Study area for an aerial survey of muskox in the Sahtu Settlement Area, March 1997

METHODS

We used a stratified linear strip transect survey design. Transect width was 500 m on each side of the aircraft for a total width of 1.0 km. For the initial survey which covered the entire study area, we spaced the transects at 10 km intervals to give 10% coverage. Transects ran east-west in order to minimize ferry time (Figure 2). To increase precision, we resurveyed two areas of high muskox density using transects with 4.5 km spacing to increase coverage to 25%.

We placed tape markers on the rear windows of the aircraft to designate the outside boundary of the transect at our planned survey altitude of 200 m above ground level. The markers were positioned by flying perpendicular to the Colville Lake runway and checking against objects placed at either end of the runway 500 m from its centre.

A strip transect survey (10% coverage) was flown in a Cessna 185 wheel/ski-equipped aircraft on 11, 12, 16, 18, 19, and 21 March, 1997. On 22 and 27 March an additional 25% coverage survey was flown over two areas of higher muskox density previously surveyed to assess the efficacy of the 10% coverage. The survey conditions for these dates were identical to the 10% survey, but transect spacing was reduced to 4.5 km intervals (Figure 3). On 16, 18, 21, and 22 March there was no right rear observer, so the navigator/data recorder also had to observe on those days. The survey was flown from Colville Lake on 11-18 March, from Kugluktuk on 19-22 March, and from Norman Wells on 27 March.

The survey team consisted of two rear seat observers and a navigator/data recorder in front with the pilot.

Observations of wildlife species seen, both on and off transect, were recorded on data forms and on 1:500,000 aeronautical charts, with locations determined by the aircraft's on-board global positioning system. While we attempted to count all wildlife groups encountered of each species, we spent considerably more time over groups of muskoxen to obtain an accurate count and to classify them to adult (>1-yr-old) and calf (<1-yr-old) categories. Calves were determined by their lack of horns and their relative size. We did not try to differentiate adult male and female muskoxen as repeated circling of the aircraft would have disturbed the animals.

We calculated size of the study area, and the length/area of each transect, using *SPANS* (ver. 5.0; TYDAC Technologies Inc., Nepean, ON) and *ARC/INFO* (ver. 7.1.1; Environmental Systems Research Institute, Inc., Redlands, CA) geographic information systems (GIS). All muskoxen and other species location and classification data for the 1997 survey were entered into the *ARC/INFO* GIS. I used Jolly's Method 2 (Jolly 1969 *in* Krebs 1989) for unequal length transects (the Ratio Method) to estimate population size, variance and the coefficient of variation for the estimates.

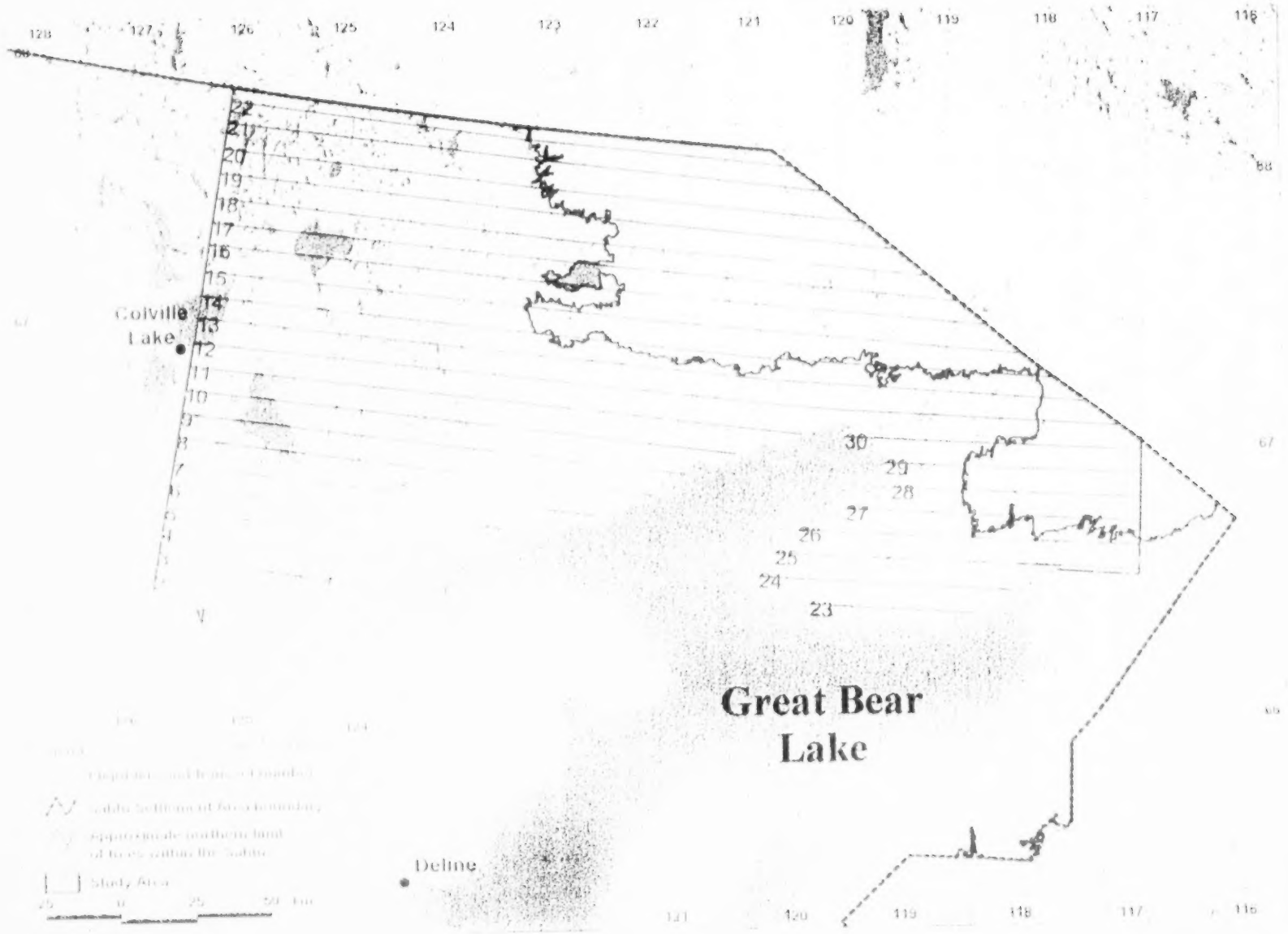

Figure 2 Transects flown during a 10% coverage aerial survey of muskox in the Sahtu Settlement area, 11-21, March 1997

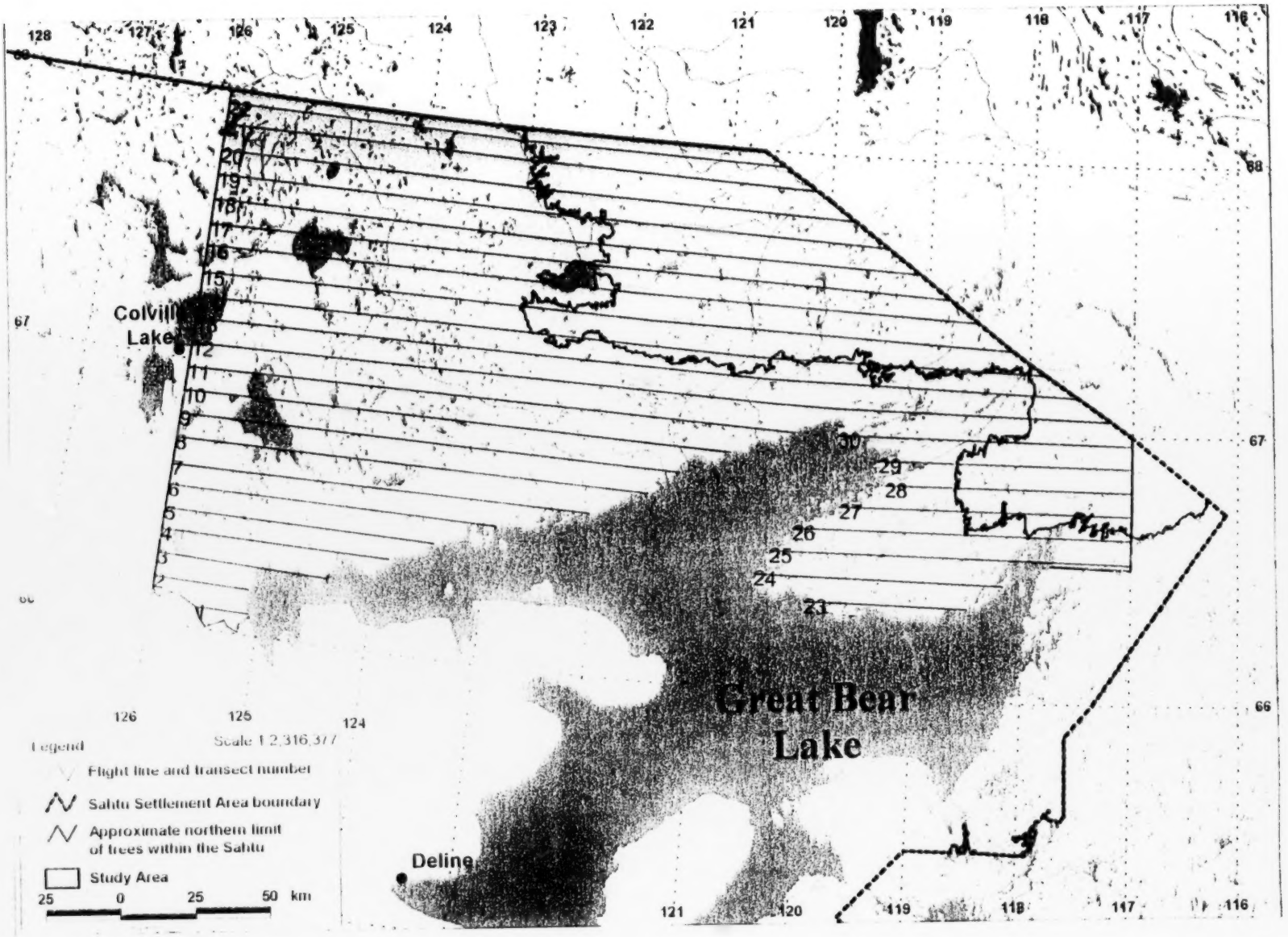

Figure 2. Transects flown during a 10% coverage aerial survey of muskox in the Sahtu Settlement area, 11-21, March 1997

RESULTS

Survey Characteristics

The 10% survey was flown over 12 days from 10 March to 21 March, 1997 and required 69.1 h of flight time (Table 3, Appendices A and B), of which 36.9 h were flown on transect and 32.2 h were used for ferry time to and from transects, moving personnel, and other logistics. The weather was good for those days when we flew the transects; poor weather precluded flying transects on three days (13-15 March). No transects were flown on 17 March due to aircraft mechanical problems.

For logistical and weather-related reasons we divided five of the longer transects into shorter sections that were flown on two or three different days (Appendix B). The mean ground speed was 154 kmph while on transect, but strong winds, especially over upland areas, gave ground speeds from 117 to 224 kmph (Appendix B).

Forested western sections of the study area were more difficult to survey due to reduced visibility within the sometimes dense trees; however, generally good visibility made tracks obvious in the snow, which aided detection of animals within the trees.

The 25% survey was flown on 22 and 27 March with a total of 11.7 h flight time, of which 5.2 h were on transect (Table 3). On 22 March we aborted the survey in a low ceiling, snow, and high winds encountered along the north shore of Great Bear Lake even though the weather conditions in Colville Lake and Norman Wells on that day were very good (Table 3). On 27 March the weather and track observation conditions were excellent. The mean ground speed for this survey was 139 kph (Appendix B).

Population Characteristics and Distribution

For the 10% survey, I calculated a population estimate of 1457 ± 448 (standard error, SE) non-calf muskoxen in the study area (Appendix C); the 95% confidence interval was 1457 ± 919 adult muskoxen (i.e., 538 to 2376). Density was approximately 26 non-calf muskoxen per 1000 km^2. The coefficient of variation (CV) for the 10% survey is 0.31. Calves were 17.7% (32 of 181) of all muskoxen observed on transect and 14.7% (48 of 327) of all muskoxen seen on and off transect during the 10% survey.

For a 2709 km^2 high muskox density area in the vicinity of Smith Arm and Omstead Creek I calculated a population estimate of 226 ± 89 (SE) adult muskoxen (i.e., 81 muskoxen/1000 km^2; Figure 3; Appendix D) from the 25% survey, with a CV of 0.39. For this same area I also calculated a population estimate of 561 ± 696 (SE; density 201/1000 km^2) from 89 adult muskoxen observed on transect within the same 2709 km^2 area during the 10% survey (Appendix D). The imprecision of this latter estimate is readily apparent from the large standard error and the CV of 1.24.

Mean herd size was the same during both the 10% and 25% surveys: 11.3 ± 3.0 and 11.3 ± 5.3, respectively (Tables 4 and 5; SE of 3.0 and 5.3, respectively); the largest group observed in the 10% survey was 62 animals and in the 25% survey the largest was 46 animals (Appendix A). For the 10% survey, mean group size was highest in areas of alpine tundra (21.3 ± 12.2 animals) and lowest in barren tundra (6.5 ± 2.8 animals). Conversely, off transect observations showed the highest group size in barren tundra (19.4 ± 7.8 animals), although in open country larger groups were more likely to be spotted at distances >500 m from the aircraft. For the 25% survey the highest mean group size on transect was recorded in closed forest habitat (16.3 ± 10.5 animals).

Muskox distribution was not even across the study area (Figure 4) and two large areas had no muskoxen, or sign of them: west of the Anderson River and >20 km north of the Great Bear Lake shoreline, and Caribou Point. The three main areas of higher muskox densities were: the Smith Arm area, Omstead Creek eskers area, and Bebensee Lake (Figure 4).

During ferry trips to and from the study area two additional groups of muskoxen were found outside the study area boundaries, between the Hare Indian River and Norman Wells (Figure 5; Table 5). Herds near Turton Ridge and Lennie Lake had 34 and 20 muskoxen, respectively. The herd near Lennie Lake herd was <30 km from Norman Wells on 27 March.

Other Species

We recorded seven other mammalian species on transect during the 10% survey (Figure 6; Table 6). The most numerous were caribou (585 animals in 15 groups) and moose (28 animals in 19 groups). Caribou were widely, but unevenly, distributed across the study area (Figure 6). The majority (62.1%) were on barren-ground tundra (Table 7), especially on the uplands east of Caribou Point. Only seven groups of caribou were observed below treeline, but old tracks in the snow provided evidence of considerably more caribou in the vicinity of Kilekale Lake and Lac des Bois earlier in the winter. No caribou were found on the upland tundra favoured by muskoxen or in the old burns and willow stands preferred by moose (Table 7). Caribou density for the study area was estimated at 102 per 1000 km^2 (Table 6).

Moose density for the study area (including tundra) was estimated at 5 per1000 km^2

(Table 6). Moose were widely distributed below treeline and most (64.3%) were located either in areas that had burned within the past ca. 25 years or in stands of willow (*Salix* spp.; Figure 6; Table 7). Calves were 8.6% (5 of 28) of moose observed. No twins or triplets were seen in the company of adult female moose.

Only six wolves, all solitary, were seen during the course of the 10% survey (Table 6) and none during the 25% survey; wolves were observed both above and below treeline (Figure 6). No tracks of wolf packs were observed during the 10% survey, nor were wolves or wolf tracks seen during ferry trips between the study area and Kugluktuk. A pack of three wolves was seen near the community of Colville Lake on 17 March and all were subsequently harvested by a local trapper. Wolf density for the study area was estimated to be 1 per 1000 km^2 (Table 7).

We observed two red foxes (*Vulpes vulpes*) in a copulatory tie on 16 March; six red foxes and one arctic fox (*Alopex lagopus*) were observed in the 10% coverage survey (Figure 6). Not surprisingly, all foxes were seen in the open barren-ground tundra. Only two wolverines (*Gulo gulo*) were observed; both were below treeline.

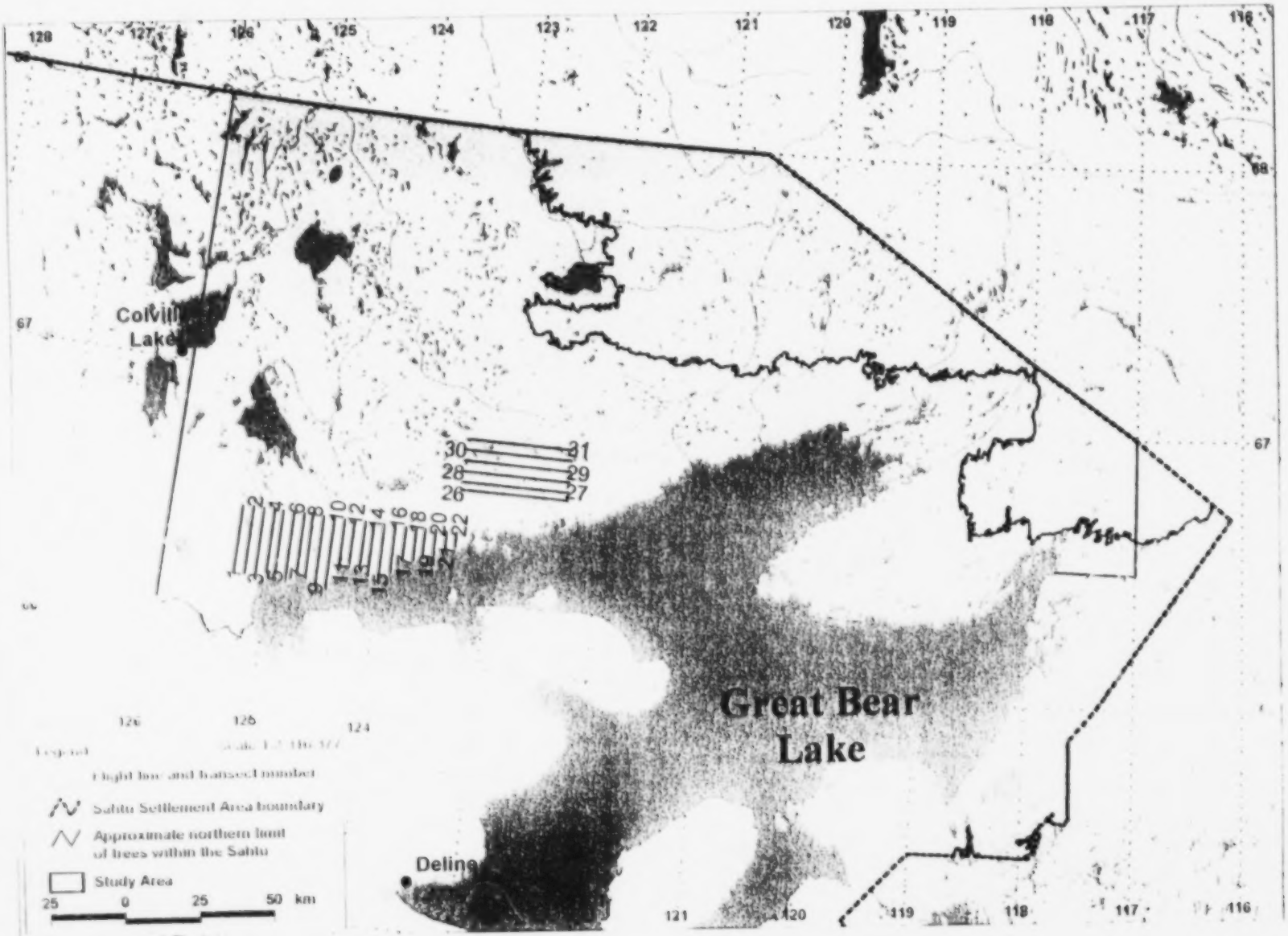

Figure 3. Transects flown during a 25% coverage aerial survey of muskox in the Sahtu Settlement area, 22 and 27 March, 1997

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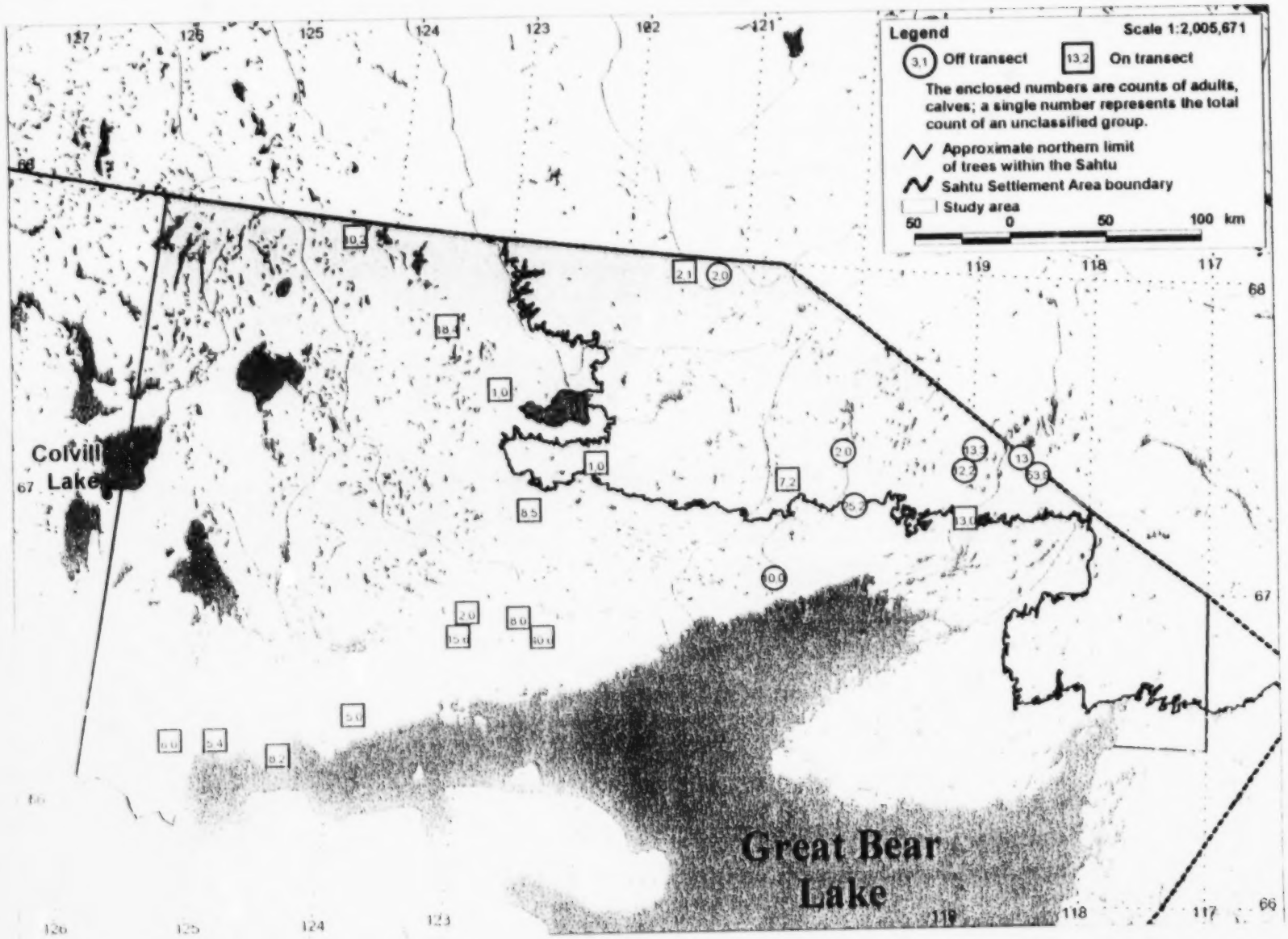

Figure 4 Location and composition of all groups observed (on and off transect) during a 25% coverage aerial survey of muskox in the Sahtu Settlement Area, 22 and 27 March, 1997

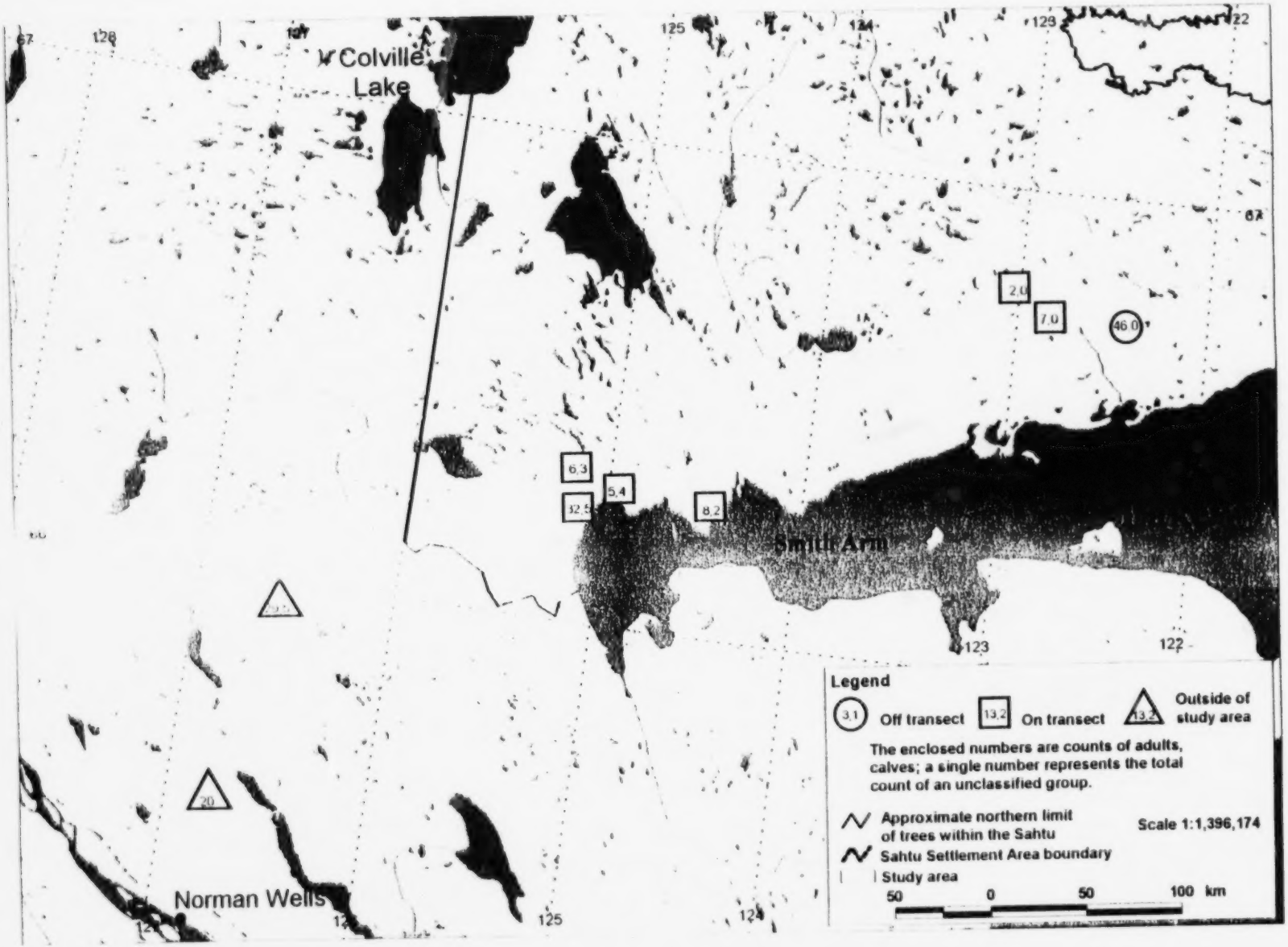

Figure 5. Location and composition of all groups observed (on and off transect) during a 25% coverage aerial survey of muskox in the Sahtu Settlement Area, 22 and 27 March, 1997

Legend
Scale 1:2,005,671
Off transect
On transect
The enclosed numbers are counts of adults, calves; a single number represents the total count of an unclassified group
Approximate northern limit of trees within the Sahtu
Sahtu Settlement Area boundary
Study area
50 0 50 100 km
Colville Lake
Great Bear Lake
119

Figure 4 Location and composition of all groups observed (on and off transect) during a 25% coverage aerial survey of muskox in the Sahtu Settlement Area, 22 and 27 March, 1997

Colville Lake
Great Bear Lake
Smith Arm
Norman Wells
Legend
Off transect
On transect
Outside of study area
The enclosed numbers are counts of adults, calves, a single number represents the total count of an unclassified group
Approximate northern limit of trees within the Sahtu
Sahtu Settlement Area boundary
Study area
Scale 1:1,396,174
50 0 50 100 km

Figure 5. Location and composition of all groups observed (on and off transect) during a 25% coverage aerial survey of muskox in the Sahtu Settlement Area, 22 and 27 March, 1997.

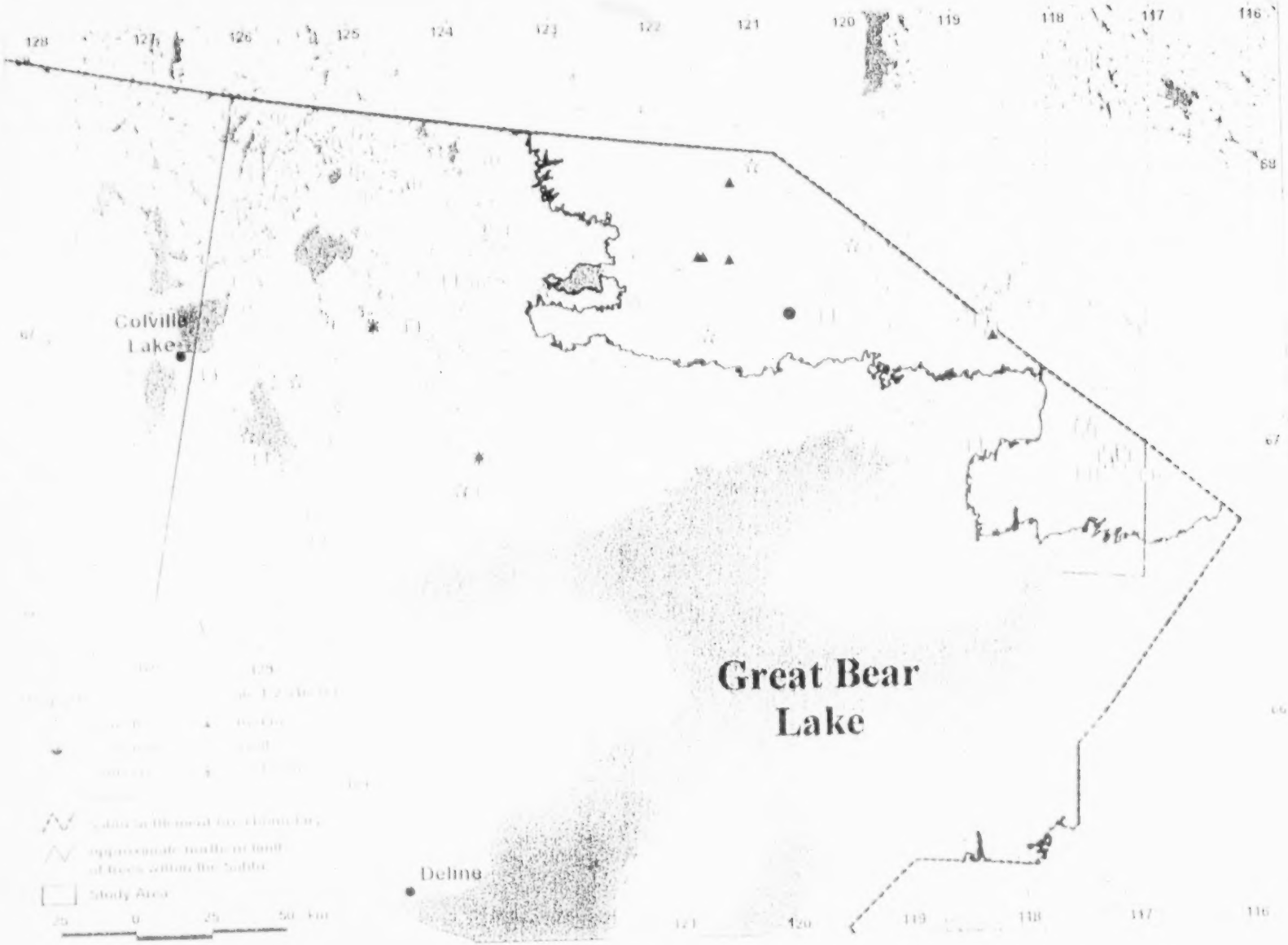

Figure 6. Locations of other species observed during an aerial survey of muskox (10% coverage) in the Sahtu Settlement Area, 11-21 March, 1997. The number of individuals observed in each group is presented in Appendix 2.

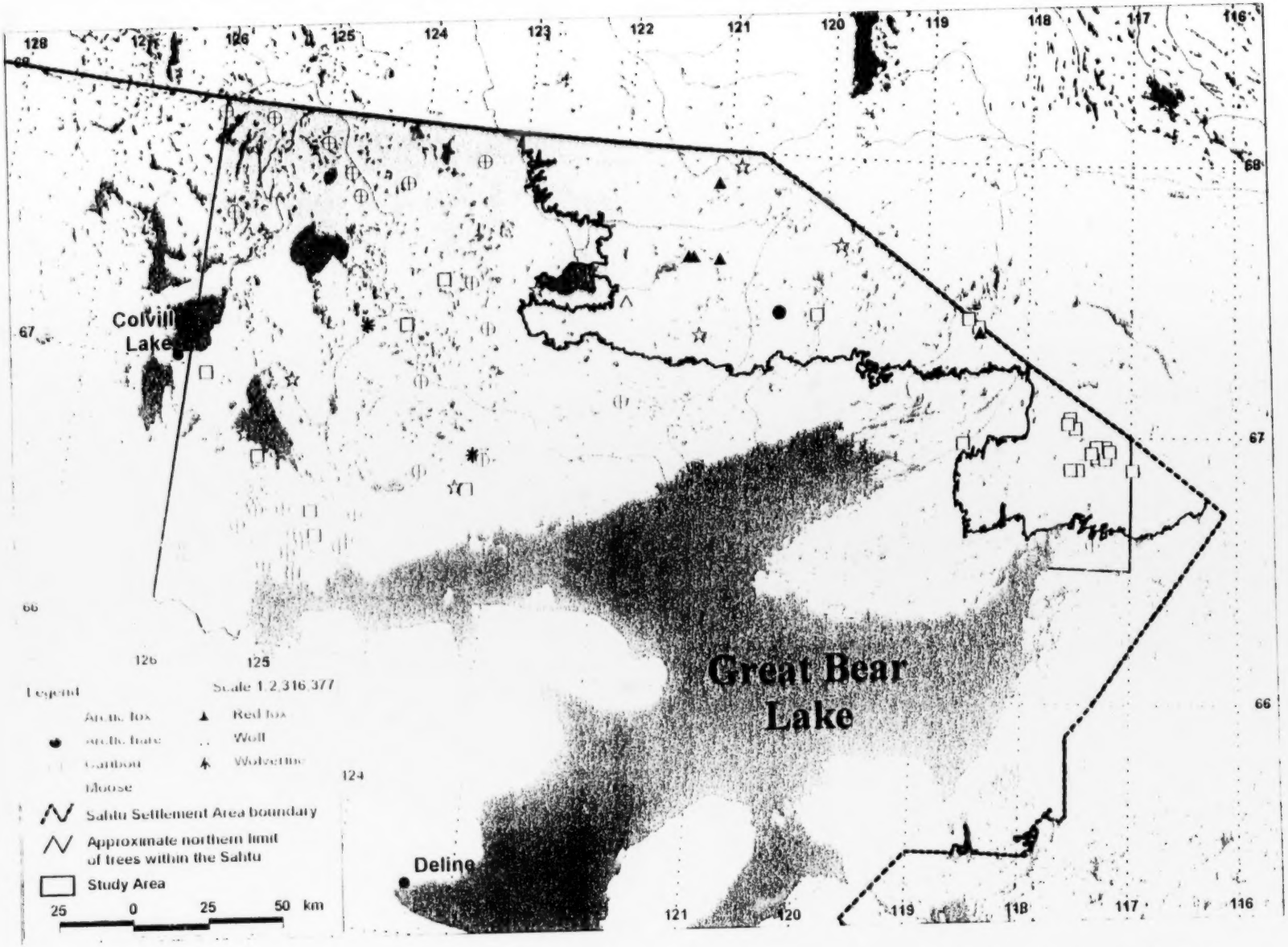

Figure 6. Locations of other species observed during an aeral survey of muskox (10% coverage) in the Sahtu Settlement Area, 11-21 March, 1997. The number of individuals observed in each group is presented in Appendix 2.

Table 3. Weather conditions (0800 and 1600 h) and flight times during an aerial survey for muskoxen in the Sahtu Settlement Area, March 1997.

	0800 h Weather Conditions					1600 h Weather Conditions					Flight Time (h)		
Date	Cloud (%)	Temp (C)	Wind[1]	Visibility	Light[2]	Cloud (%)	Temp (°C)	Wind[1]	Visibility	Light[2]	..ry	Transect	Total
10% Coverage Survey													
10-Mar	100	-25	NW 30	poor	flat/medium	70	-21	NW 20	good	bright/medium	5.3	0.0	5.3
11-Mar	60	-29	NW 15	fair	flat/medium	20	-25	W 20	excellent	bright/high	2.2	3.3	5.5
12-Mar	0	-22	SW 5	excellent	bright/medium	0	-15	W 5	excellent	bright/high	0.9	5.8	6.7
13-Mar	100	-13	SW 30	poor	flat/low	100	-8	SW 30	poor	flat/low	1.0	0.0	1.0
14-Mar	100	-10	SW 40	poor	flat/low	100	-6	SW 40	poor	flat/low	4.3	0.0	4.3
15-Mar	100	-23	NW 10	poor	flat/low	50	-25	NW 15	fair	flat/medium	1.1	0.0	1.1
16-Mar	30	-28	NW 5	good	flat/medium	20	-20	NW 5	good	bright/medium	2.7	7.6	10.3
17-Mar	0	-30	S 5	excellent	bright/medium	0	-18	S 5	excellent	bright/high	1.0	0.0	1.0
18-Mar	0	-38	NE 5	excellent	bright/medium	0	-25	NE 10	excellent	bright/high	1.7	8.9	10.6
19-Mar	75	-19	SE 20	fair	flat/medium	100	-18	NE 20	poor	flat/medium	4.4	2.1	6.5
20-Mar	40	-18	E 5	good	bright/medium	20	-20	E 5	excellent	bright/high	4.0	6.3	10.3
21-Mar	20	-29	nil	excellent	bright/medium	20	-10	NE 5	excellent	bright/high	3.6	2.9	6.5
									Total Flight Time:		32.2	36.9	69.1
25% Coverage Survey													
22-Mar	100	-22	E 5	fair	flat/medium	75	-5	nil	v good	bright/medium	3.5	1.8	5.3
27-Mar	0	-33	nil	excellent	bright/medium	20	-15	SW 10	exc ..llent	bright/medium	3.0	3.4	6.4
									Total Flight Time:		6.5	5.2	11.7

[1] Direction and estimated speed (kmph)

[2] Light type/ intensity

Table 4. Muskox distribution by habitat type during a 10% coverage aerial survey in the Sahtu Settlement Area, March 1997.

Habitat Type	No. Groups[1]	Mean Group Size ± SE	Muskoxen Observed			
			Adults	Calves	Unknown	Total
		On Transect				
Barren Tundra	4	6.5 ± 2.8	23	3	0	26
Alpine Tundra	3	21.3 ± 12.2	56	8	0	64
Closed Forest	2	8.5 ± 3.5	15	2	0	17
Open Forest	7	10.6 ± 3.2	55	19	0	74
Total	16	11.3 ± 3.0	149	32	0	181
		Off Transect				
Barren Tundra	7	19.4 ± 7.8	107	16	13	136
Open Forest	1	n/a	10	0	0	10
Total	8	18.3 ± 6.9	117	16	13	146

[1] includes 2 single muskoxen

Table 5. Muskox distribution by habitat type during a 25% coverage aerial survey in the Sahtu Settlement Area, March 1997 and for two groups of muskoxen located outside the study area.

Habitat Type	No. Groups	Mean Group Size ± SE	Muskoxen Observed			
			Adults	Calves	Unknown	Total
		On Transect				
Barren Tundra		Habitat not represented in survey area				
Alpine Tundra	3	6.3 ± 2.3	17	2	0	19
Closed Forest	3	16.3 ± 10.5	41	8	0	49
Open Forest	0	-	0	0	0	0
Total	6	11.3 ± 5.3	58	10	0	68
		Off Transect				
Open Forest	1	n/a	46	0	0	46
		Outside Study Area				
Alpine Tundra	1	n/a	29	5	0	34
Open Forest	1	n/a	0	0	20	20
Total	2	n/a	29	5	20	54

Table 6. Numbers and estimated abundance of all mammalian species observed on transect during a 10% coverage aerial survey for muskoxen in the Sahtu Settlement Area, 11-21 March, 1997.

Species	No. Groups	No. Individuals	Density Per 1000 km^2	Study Area Population Estimate
Muskox (adult)	16	149	26	1457 $\pm$ 448 (SE)
Barren-ground	15	585	102	5693
Moose	19	28	5	274
Wolf	6	6	1	59
Wolverine	1	1	n/a	n/a
Red Fox	4	5	n/a	n/a
Arctic Fox	1	1	n/a	n/a
Arctic Hare	1	1	n/a	n/a

Table 7. Habitat types used by muskoxen, barren-ground caribou, and moose during a 10% coverage aerial survey for muskoxen in the Sahtu Settlement Area, 11-21 March, 1997.

Habitat	Muskox			Moose			Caribou		
	Groups	N	% of Total	Groups	N	% of Total	Groups	N	% of Total
Open Spruce	7	74	40.9	3	4	14.3	1	3	0.5
Closed Spruce	2	17	9.4	3	5	17.9	4	134	22.9
Burn	0	0	0	6	10	35.7	0	0	0
Willow	0	0	0	6	8	28.6	0	0	0
Alpine Tundra	3	64	35.4	0	0	0	0	0	0
Barren-ground	4	26	14.4	0	0	0	8	363	62.1
Lake	0	0	0	1	1	3.6	2	85	14.5
Total	16	181	100	19	28	100	15	585	100

Table 8. North Great Bear Lake muskox herd size, 1953-1997.

Year	Month	Mean Size[a]	Group S.E.[a]	Range	No. Singles	N[a]	Source
1953	Feb	28.7	14.7	2-63	0	3	Kelsall et al. (1971)
1955	Mar	10.5	3.2	1-25	1	6	Kelsall et al. (1971)
1958	Mar	17.0	5.0	4-32	0	5	Kelsall et al. (1971)
1966	Apr	19.8	4.3	1-35	1	5	Carruthers and Jakimchuk (1981)
1967	Mar	21.0	11.7	6-73	0	5	Kelsall et al. (1971)
1967	Apr	14.0	4.6	2-50	0	9	Kelsall et a. (1971)
1974	Mar	20.4	3.4	2-90	0	51	Carruthers and Jakimchuk (1981)
1980	Mar	16.3	1.5	1-75	9	91	Carruthers and Jakimchuk (1981)
1983	Mar	21.1	17.0	1-100	4	143	Case and Poole (1985)
1987	Aug	20.7	16.5	1-70	15	23	McLean (1992)
1997	Mar[b]	11.4	2.6	1-45	4	21	Larter (1997)
1997	Mar[b,c]	12.8	3.0	1-46	2	14	This study

[a] Excluding single animals
[b] Only animals observed on-transect included
[c] Data from 10% coverage survey

DISCUSSION

Survey Design

The timing of the survey in March was optimal with high visibility afforded by large, dark animals on a white background, easily detectable tracks in the snow, long days, and generally good weather. Case and Poole (1985: 22) suggested that July surveys would be preferable to March because muskox distribution would be more predictable and the delineation of high density strata easier. However, McLean (1992) surveyed muskoxen north of Great Bear Lake in August 1987 and still encountered problems with clumped distribution of animals, but without the benefit of having snow and tracks to increase the chance of seeing animals. This is especially important below treeline where trees, particularly in closed canopy forest, greatly reduce visibility.

The 25% survey in two of the higher density muskox areas did not improve precision over the 10% survey, and problems with this survey precluded its use in reducing the CV of the estimate calculated from the 10% survey. Indeed, the 0.39 CV of the 25% survey was higher than the 0.31 CV of the overall 10% survey (0.31). At 25% coverage we saw only 58 adult muskoxen on transect in 715 km^2, whereas we saw 89 adult muskoxen in 425 km^2 during the 10% transects for the same area. There was a group of 40 adult and 6 calf muskoxen observed on transect in the 10% survey that was not seen in the 25% survey. Similarly, a group of 46 adults observed off transect in the 25% survey was not seen in the 10% survey. I am confident in both classifications and it is likely that most of the animals were classified twice in groups of changing composition given the numbers of individuals involved, the open terrain, the 3 km that separated the two locations (66°48'N, 122°35'W

and 66°47'N, 122°33'W), and the 14 days between the two classifications. A group of 32 adult and 5 calf muskoxen seen in closed forest habitat in the Smith Arm area in the 25% survey was not seen in the 10% survey. Cleary animals were missed by observers at both coverage levels, but the extent is unknown.

A total of 146 muskoxen were observed off transect during the 10% survey (81% of the number observed on transect) and 46 in the 25% survey (68% of the number observed on transect. Larter (1997) used 1 km-wide transects in his muskox survey in the Inuvialuit Settlement Region during 10-19 March and saw 143 muskoxen off transect, which was 50% the number on transect. Case and Poole (1985) had similar problems in their March 1983 muskox survey with more muskoxen observed off transect (1.5 km-wide) than on transect for some transects. They suggested that spring surveys over open terrain could have transects even wider than 1.5 km; however, they acknowledged visibility was a problem within the trees, even with relatively narrow 1.5 km transects.

Problems encountered during this survey that contributed to overall survey bias include: loss of several days to weather and aircraft mechanical problems, observer fatigue (sleeping observers see fewer animals), observer inexperience (it was the first muskox survey for all observers and the data recorder/navigator), the lack of a second rear-seat observer on four different days, long flight lines (up to 377 km), the large amount of forested area that was covered, and considerable variability in average speed on individual flight lines due to wind direction and velocity. Although the survey was interrupted for several days, it is not likely that movements of muskoxen affected the population estimate, since muskox movements in late winter are generally localized to within a few kilometers (Larter, pers. comm.).

Observer experience and ability is critical to the success of an aerial survey. In Alaska even experienced moose surveyors in small fixed-wing aircraft missed 32% of the moose present on quadrats and inexperienced observers missed 57% (LeResche and Rausch 1974). Caughley (1974) and Caughley et al. (1976) concluded that aircraft speed, height above ground, transect width, and observer differences in ability to see animals all have significant effects on the results of aerial surveys, whereas time of day, fatigue of observers, and length of survey are of lesser importance. We experienced problems in maintaining a constant aircraft speed and altitude, which would in turn affect the accuracy of our population estimate. I believe that reducing the transect width to 1 km was beneficial to the survey, especially below treeline, and we were not able to use only experienced observers given the requirement for active community participation in the survey. Given these sources of bias, it is clear that the population estimate is a minimum as all the biases result from observers missing animals rather than over-counting.

Population Characteristics and Distribution

The population estimate of 1457 $\pm$ 448 (SE) from the 10% survey, or a density of 26 adult muskoxen per 1000 km^2, does not appear to represent a population increase since 1983 (Case and Poole 1985) and 1987 (McLean 1992). Case and Poole estimated 1083 $\pm$ 553 (SE) adult muskoxen, or 161 per 1000 km^2, in Stratum 5 of their survey alone (Estabrook Lake to Horton Lake). McLean (1992) estimated 11 adult muskoxen per 1000 km^2 for the Sahtu portion of his survey; however, problems with his survey strongly suggest that this was a substantial underestimate. Larter's (1997) estimate of 2567 $\pm$ 724 (SE) adult muskoxen (70 per 1000 km^2) for the ISR is also similar to previous estimates for that

region in the 1980's.

The calf percentage of 14.3% (45 of 314) for muskoxen observed on and off transect during the 10% survey compares favourably with previous estimates for 1983 (10.5%) north of Great Bear Lake (Case and Poole 1985), and with Larter's (1997) survey in the ISR (11.5%). Because muskoxen calve in April-May (Lent 1978; Gunn 1982) calf composition estimates in March reflect the maximum rate of recruitment to the adult (i.e., >1-yr-old) segment of the population. The estimated rate of 14.3% for this survey suggests recruitment was good in 1997.

The area around Smith Arm of Great Bear Lake was not covered in the March 1983 or August 1987 surveys. However, a telemetry study of two adult female muskoxen by Latour (1992), and the 1997 survey, clearly indicate that muskoxen have become well established below treeline in the vicinity of Smith Arm. In addition, muskoxen in the Sahtu are continuing their colonizing movements southwestward, as shown by the two herds seen outside the study area in the Turton Ridge and Lennie Lake areas.

Latour (1992) placed satellite-tracked radiocollars on two adult female muskoxen captured at Smith Arm on 25 Feb 1991, then monitored their movements from then until 11 Nov 1992. The two cows remained below treeline for the entire periods they were radio-tracked (ca. 21 and 17 months). One stayed within 30 km of the capture site, whereas the other travelled from Smith Arm to the north shore of Great Bear Lake mid-way between Good Hope and McGill Bays in July 1991, then remained there until July 1992 when the radiocollar apparently failed (Latour 1992).

Distribution of muskoxen in the 1997 survey differed from earlier surveys (Case and Poole 1985; McLean 1992), but areas were surveyed (e.g., Smith Arm, Bebensee Lake,

and Caribou Point) that had not been covered in 1983 or 1987. In 1983 most animals were found in the vicinity of Estabrook and Stopover Lakes, whereas in 1987 the majority were in the Horton Lake area and upper Omstead Creek. Surprisingly, few muskoxen were seen in the Estabrook, Stopover, and Horton Lake areas in this survey. The 35 muskoxen observed on and off transect during the 10% survey in the vicinity of these lakes was considerably less than the 167 recorded by McLean (1992) in August 1987 and the 284 seen in March 1983 over 1759 km^2 (Case and Poole 1985).

Harvest and Management Recommendations

1) The current quota of 11 animals per year for the SSA is within accepted limits for the estimated population of 1457 $\pm$ 448 (SE) adult muskoxen (0.8% of the estimated population size). A quota increase to 5% of the lower 95% confidence interval (N=538) for the estimated adult population size would not endanger the continued health and range expansion of muskoxen in the Sahtu. Therefore, I recommend an annual quota of 27 adult muskoxen for the Sahtu Settlement Area.

2) The distribution of muskoxen in the SSA is not even and any increase in quota must ensure that harvest is evenly distributed and not localized in those areas that are most easily accessed (e.g., north shore of Great Bear Lake in the Smith Arm and Good Hope Bay areas, Lennie Lake, Turton Ridge). If the quota is increased from the current level, the current Sahtu Muskox Area S/MX/01 should be subdivided into zones that would each receive a portion of any new quota. This, and allocation of tags to communities, RHL holders, and outfitters should be determined by the Sahtu Renewable Resources Board in conjunction with the

community Renewable Resource Councils, the Regional Renewable Resource Council, and the Department of Resources, Wildlife, and Economic Development.

3) The time span between population surveys for muskoxen in the SSA should be reduced from 10 years to 5 years, particularly if changes to harvest quotas (and actual harvest) occur.

4) Future surveys should include the same area flown in March 1997, should be done in March using similar methods to those described here, and should be coordinated to coincide with similar efforts north of the SSA boundary with the ISR (Larter 1997). However, consideration should be given to developing methods for treed areas.

5) During future surveys, sufficient time and funds should be allocated to ensure that all higher density areas surveyed at 10% can be reflown at $\geq$25% coverage.

6) Muskox herds located outside the March 1997 study area should be occasionally monitored by DRWED and SRRB during the course of other field work and records maintained by DRWED of sightings by pilots, resource harvesters, and others that report their observations.

ACKNOWLEDGEMENTS

I thank pilot Ken Williams (*Williams Aero*, Norman Wells) for his enthusiastic and skilled participation in this survey. Observers Joseph Blondin, Jr. from Deline (10-21 Mar), Dale Kochon from Colville Lake (11, 12, 19-22 Mar), Richard Popko (DRWED, Norman Wells; 27 Mar), and Jan Adamczewski (SRRB, Norman Wells; 27 Mar) endured long hours in the rear seats (with only minimal complaint!). I thank the Renewable Resource Councils of Deline and Colville Lake for their support for this study and for nominating Messrs. Blondin and Kochon for the survey. The Sahtu Renewable Resources Board provided major funding for the research and the survey would not have been possible without their financial assistance and support.

The original flight lines and survey maps were prepared by Richard Popko. Nic Larter and John Nagy (DRWED, Inuvik) assisted with project design and interpretation of results, and coordinated their efforts with the Sahtu Region to comprehensively survey the western Arctic mainland. Lana Leverington (GIS Specialist, SRRB) entered all data onto GIS, calculated study area size and transect lengths/areas, and produced the maps in this report. I am grateful to both Richard and Lana for their continued support, assistance, and advice.

Anne Gunn, Dr. Nic Larter, Gerry LePrieur and Richard Popko (Resources, Wildlife, and Economic Development); Dr. Jan Adamczewski (Biologist, SRRB); and Dr. Paul Latour (Canadian Wildlife Service, Yellowknife and SRRB member) kindly reviewed an earlier draft of this report. Lynda Yonge produced the report.

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APPENDIX A. Observations by location, observer, species, and habitat type during 10% and 25% coverage aerial surveys for muskoxen in northern Sahtu, 11-27 March 1997.

Date	Transect No.	Obsv'n No.	Observer	Adult	Calves	Unknown	Total	Species	On/Off Transect	Lat (N)	Lon (W)	Habitat
					10% Coverage Survey							
11Mar97	3	1	L	6			6	Muskox	On	66	125 18	Open forest
11Mar97	3	2	L	5	4		9	Muskox	On	66	125 08	Open forest
11Mar97	3	3	L	8	2		10	Muskox	On	66	124 26	Alpine
11Mar97	4	4	L			2	2	Moose	On	66	124 49	Burn
11Mar97	5	5	R	2			2	Moose	Off	66	125 19	Burn
11Mar97	5	6	R	1	1		2	Moose	On	66	124 46	Burn
11Mar97	5	7	R	16			16	Caribou	On	66	124 36	Lake
11Mar97	5	8	L			1	1	Moose	Off	66	124 18	Burn
11Mar97	5	9	L	5			5	Muskox	On	66	123 52	Closed
11Mar97	6	10	R	2			2	Moose	On	66	124 15	Burn
11Mar97	6	11	L			10	10	Caribou	On	66	124 40	Closed
11Mar97	6	12	L	1	1		2	Moose	On	66	124 55	Burn
11Mar97	6	13	R	1			1	Moose	On	66	125 12	Burn
12Mar97	8	14	R	15	6		21	Muskox	On	66	123 06	Open forest
12Mar97	8	15	R	1	1		2	Moose	On	66	123 42	Willow
12Mar97	8	16	R			3	3	Caribou	On	66	125 14	Open forest
12Mar97	9	17	L	1			1	Wolf	On	66	125 23	Lake
12Mar97	9	18	L			1	1	Wolverine	On	66	123 13	Closed
12Mar97	9	19	L	2			2	Muskox	On	66	123 03	Open forest
12Mar97	9	20	L	40	6		46	Muskox	On	66	122 35	Alpine
12Mar97	9	21		8			8	Muskox	On	66	122 38	Alpine
16Mar97	22	22	L	1	1		2	Moose	On	67	126 00	Willow
16Mar97	22	23	L	1			1	Moose	On	67	125 31	Lakeshore
16Mar97	22	24	L	10	2		12	Muskox	On	67	124 21	Closed
16Mar97	22	25	R	2	1		3	Muskox	On	67	121 31	Barrens
16Mar97	22	26	L	2			2	Muskox	Off	67	121 13	Barrens
16Mar97	22	27	L	1			1	Wolf	On	67	120 52	Barrens
16Mar97	21	28	R	2			2	Red fox	On	67	121 05	Barrens

Date	Transect No.	Obsv'n No.	Observer	Adult	Calves	Unknown	Total	Species	On/Off Transect	Lat (N)	Lon (W)	Habitat
16Mar97	21	29	L	1			1	Moose	On	67	123 24	Open forest
16Mar97	21	30	R	1			1	Moose	On	67	124 57	Willow
16Mar97	20	31	L	1			1	Moose	On	67	124 41	Willow
16Mar97	20	32	L	2			2	Moose	On	67	124 07	Open forest
16Mar97	19	33	L	1			1	Wolf	On	67	119 51	Barrens
16Mar97	19	34	R	18	4		22	Muskox	On	67	123 29	Open forest
16Mar97	19	35	R	1			1	Moose	On	67	124 34	Willow
16Mar97	18	36	L	1			1	Moose	On	67	125 46	Open forest
18Mar97	18	37	L			1	1	Red fox	On	67	121 20	Barrens
18Mar97	18	38	R			1	1	Red fox	On	67	121 17	Barrens
18Mar97	18	39	L			1	1	Red fox	On	67	121 02	Barrens
18Mar97	17	40	L	1			1	Muskox	On	67	122 59	Open forest
18Mar97	16	41	L			30	30	Caribou	Off	67	123 40	Closed
18Mar97	16	42	R	1			1	Moose	On	67	123 24	Willow
18Mar97	16	43	R	1			1	Wolf	On	67	122 46	Closed
18Mar97	14	44	R	1			1	Wolverine	Off	67	124 21	River
18Mar97	14	45	R			69	69	Caribou	On	67	123 59	Lake
18Mar97	14	46	L	2			2	Moose	On	67	123 12	Closed
18Mar97	16	47	L	1			1	Arctic fox	On	67	121 54	Barrens
18Mar97	16	48	L			1	1	Arctic	On	67	120 25	Barrens
18Mar97	16	49	R	2			2	Muskox	Off	67	120 04	Barrens
18Mar97	16	50	L			11	11	Caribou	On	67	120 03	Barrens
18Mar97	16	51	L	13	3		16	Muskox	Off	67	118 58	Barrens
18Mar97	16	52	R	53	9		62	Muskox	Off	67	118 29	Barrens
18Mar97	16	53	L			14	14	Caribou	Off	67	118 29	Barrens
18Mar97	16	54	R			1	1	Red fox	Off	67	118 28	Barrens
18Mar97	15	55	R	7	2		9	Muskox	On	67	120 31	Barrens
18Mar97	15	56	L	1			1	Wolf	On	67	121 10	Barrens
18Mar97	15	57	R	1			1	Muskox	On	67	122 07	Barrens
19Mar97	12	58	L	1	1		2	Moose	On	67	123 47	Closed
19Mar97	12	59	R			22	22	Caribou	Off	67	117 35	Barrens
19Mar97	12	60	R			33	33	Caribou	On	67	117 34	Barrens
19Mar97	12	61	R			41	41	Caribou	Off	67	117 36	Barrens

Date	Transect No.	Obsv'n No.	Observer	Adult	Calves	Unknown	Total	Species	On/Off Transect	Lat (N)	Lon (W)	Habitat
19Mar97	12	62	L			80	80	Caribou	On	67	117 36	Barrens
20Mar97	26	63	R	1			1	Moose	On	66	117 21	Burn
20Mar97	14	64	R	13			13	Muskox	On	67	119 02	Barrens
20Mar97	14	65	R	25	2		27	Muskox	Off	67	119 57	Barrens
20Mar97	30	66	L			50	50	Caribou	On	66	117 17	Barrens
20Mar97	30	67	L			13	13	Caribou	On	66	117 18	Barrens
20Mar97	30	68	R			17	17	Caribou	On	66	117 19	Barrens
20Mar97	30	69	R			150	150	Caribou	On	66	117 21	Barrens
20Mar97	30	70	R			100	100	Caribou	Off	66	117 14	Barrens
20Mar97	30	71	R			12	12	Caribou	Off	66	117 12	Barrens
20Mar97	29	72	L			40	40	Caribou	Off	66	116 59	Barrens
20Mar97	29	73	L			9	9	Caribou	On	66	117 30	Barrens
20Mar97	29	74	R			8	8	Caribou	Off	66	117 34	Barrens
20Mar97	30	75	L			100	100	Caribou	On	66	118 36	Closed
20Mar97	30	76	R			12	12	Caribou	On	66	118 36	Closed
21Mar97	13	77	R	8	5		13	Muskox	On	67	122 38	Open forest
21Mar97	12	78	L	1			1	Moose	On	67	121 52	Closed
21Mar97	12	79	L	10			10	Muskox	Off	67	120 34	Open forest
21Mar97	11	80	R	1			1	Wolf	On	67	125 00	Lake
21Mar97	11	81	L			12	12	Caribou	On	66	125 49	Closed
21Mar97	16	102	R			13	13	Muskox	Off	67	118 35	Barrens
21Mar97	16	103	R			31	31	Caribou	Off	67	118 35	Barrens
21Mar97	16	104	R	12	2		14	Muskox	Off	67	119 03	Barrens
					25% Coverage Survey							
22Mar97	2	82	L	1	1		2	Moose	Off	66	125 10	Burn
22Mar97	3	83	R	3			3	Muskox	On	66	125 08	Closed
22Mar97	3	84	R	6	3		9	Muskox	On	66	125 07	Closed
22Mar97	4	85	L	32	5		37	Muskox	On	66	125 03	Closed
22Mar97	4	86	L	1			1	Moose	On	66	125 02	Burn
22Mar97	6	87	L	2			2	Moose	On	66	124 50	Burn
22Mar97	7	88	L	1			1	Moose	On	66	124 45	Burn
22Mar97	7	89	R	1	1		2	Moose	On	66	124 45	Burn

Date	Transect No.	Obsv'n No.	Observer	Adult	Calves	Unknown	Total	Species	On/Off Transect	Lat (N)	Lon (W)	Habitat
22Mar97	7	90	R	1			1	Moose	Off	66	124 45	Burn
27Mar97	10	91	R	8	2		10	Muskox	On	66	124 28	Alpine
27Mar97	11	92	L	1			1	Moose	On	66	124 21	Closed
27Mar97	11	93	L	1			1	Moose	On	66	124 21	Closed
27Mar97	26	94	R			7	7	Caribou	Off	66	123 15	Lake
27Mar97	27	95	L	1			1	Wolf	On	66	123 18	Closed
27Mar97	29	96	R	46			46	Muskox	Off	66	122 33	Alpine
27Mar97	29	97	L	7			7	Muskox	On	66	122 51	Alpine
27Mar97	30	98	L	1			1	Moose	On	66	123 11	Closed
27Mar97	30	99	R	2			2	Muskox	On	66	123 03	Open forest

APPENDIX B. Transect data, flight times, average speed, and muskoxen observed on transect during an aerial survey for muskoxen in the Sahtu Settlement Area, 11 to 21 March 1997.

Transect Number	Dates Flown	Length (km)	Total Time (min)	Avg. Speed (kph)	Muskoxen On	
					Adult	Calf
		10% Coverage Survey				
1	11 Mar	22	7	187	0	0
2	11 Mar	39	20	117	0	0
3	11 Mar	69	33	125	19	6
4	11 Mar	94	48	118	0	0
5	11 Mar	112	41	164	5	0
6	11 Mar	135	50	162	0	0
7	12 Mar	170	64	160	0	0
8	12 Mar	192	93	124	15	6
9	12 Mar	206	89	139	50	6
10	12 Mar	227	100	136	0	0
11	21 Mar	250	101	148	0	0
12	19, 20, 21 Mar	377	132	171	0	0
13	18, 19, 21 Mar	361	123	176	8	5
14	18, 20 Mar	346	110	189	13	0
15	18 Mar	331	148	134	8	2
16	18 Mar	316	134	141	0	0
17	16, 18 Mar	300	116	155	1	0
18	16, 18 Mar	284	108	158	0	0
19	16 Mar	267	110	146	18	4
20	16 Mar	251	96	157	0	0
21	16 Mar	234	98	143	0	0
22	16 Mar	218	90	145	12	3
23	20 Mar	65	20	195	0	0
24	20 Mar	102	46	133	0	0
25	20 Mar	149	40	224	0	0
26	20 Mar	140	65	129	0	0
27	20 Mar	122	35	208	0	0
28	20 Mar	104	41	152	0	0
29	20 Mar	106	28	227	0	0
30	20 Mar	122	41	179	0	0
Total		5709	2227		149	32

Transect Number	Dates Flown	Length (km)	Total Time (min)	Avg. Speed (kph)	Muskoxen On	
					Adult	Calf
Average				154		
		25% Coverage Survey				
1	22 Mar	28	11	152	0	0
2	22 Mar	28	10	167	0	0
3	22 Mar	28	15	112	9	3
4	22 Mar	26	19	83	32	5
5	22 Mar	26	10	154	0	0
6	22 Mar	28	12	140	0	0
7	22 Mar	25	9	163	0	0
8	22 Mar	26	10	154	0	0
9	22 Mar	28	10	167	0	0
10	27 Mar	29	12	147	8	2
11	27 Mar	20	7	172	0	0
12	27 Mar	17	8	128	0	0
13	27 Mar	19	7	166	0	0
14	27 Mar	22	9	143	0	0
15	27 Mar	23	9	151	0	0
16	27 Mar	19	10	114	0	0
17	27 Mar	14	6	139	0	0
18	27 Mar	13	7	113	0	0
19	27 Mar	11	5	134	0	0
20	27 Mar	9	4	134	0	0
21	27 Mar	7	3	134	0	0
22	27 Mar	6	9	37	0	0
26	27 Mar	44	18	148	0	0
27	27 Mar	44	19	140	0	0
28	27 Mar	44	17	156	0	0
29	27 Mar	44	23	115	7	0
30	27 Mar	44	15	176	2	0
31	27 Mar	44	18	147	0	0
Total		715	312		58	10
Average				139		

APPENDIX C. Calculations used to derive a population estimate and 95% confidence interval from a 10% coverage aerial survey of the Sahtu Settlement Area muskox population, March 1997 using Jolly's (1969) Method 2 (the ratio method) for unequal transect lengths (Krebs 1989).

Study (stratum) area (km^2) (Z)	55, 818
No. of transects possible at 1 km intervals (N)	219
No. of transects surveyed (n)	30
Total area surveyed at 10% coverage (km^2) ($\sum z$)	5709
$\sum z^2$	1,384,636.8
Total count of adult (>1-yr-old) muskoxen on transect ($\sum y$)	149
$\sum y^2$	5376
$\sum yz$	40,081.6
Average density of adult muskoxen across the study area (R)	0.0261/km^2
	i.e., 26 muskoxen per 1000 km^2
Estimated number of adult muskoxen in the study area ($\hat{Y}=RZ$)	1457
Variance of the population estimate (Var ($\hat{Y}$))	201,101.69
Standard error of the population estimate (S.E.($\hat{Y}$) = $\sqrt{}$Var($\hat{Y}$))	448.4
95% confidence interval for the population estimate	1457 $\pm$ 919 adult muskoxen
($\hat{Y} \pm t_{0.25}$[S.E.($\hat{Y}$)]; $t_{0.25}$ for 29 d.f. is 2.05)	i.e., 538 to 2376 adult muskoxen
Coefficient of variation for the survey (CV = S.E. ($\hat{Y}$)/ $\hat{Y}$)	0.31

APPENDIX D. Population estimates and 95% confidence intervals for a high muskox density portion of the Sahtu Settlement Area surveyed with 10% and 25% coverage, March 1997. Calculations follow Jolly's (1969) Method 2 (the ratio method) for unequal transect lengths (Krebs 1989).

	10% coverage	25% coverage
Study (stratum) area (km^2) (Z)	2790	2790
No. of transects possible at 1 km intervals (N)	86	86
No. of transects surveyed (n)	8	28
Total area surveyed (km^2) ($\sum z$)	425	715
$\sum z^2$	22639.0	22093.6
Total count of adult (>1-yr-old) muskoxen on transect ($\sum y$)	89	58
$\sum y^2$	5187	1666
$\sum yz$	5130	1994.9
Average density of adult muskoxen across the study area (R)	0.201	0.081
Estimate of muskoxen per 1000 km^2	201	81
Estimated number of adult muskoxen in the study area ($\hat{Y}=RZ$)	561	226
Variance of the population estimate (Var ($\hat{Y}$))	483859.8	7903.41
Standard error of the population estimate (S.E.($\hat{Y}$) = $\sqrt{}$Var($\hat{Y}$))	695.6	88.9
95% confidence interval for the population estimate ($\hat{Y} \pm t_{0.25}$[S.E.($\hat{Y}$)]; $t_{0.25}$ for 29 d.f. is 2.05; for 7 d.f. is 2.37)	561±1649 adult muskoxen	226±182 adult muskoxen
Coefficient of variation for the survey (CV = S.E. ($\hat{Y}$)/$\hat{Y}$)	1.24	0.39